METHOD AND APPARATUS FOR GATHERING THREE DIMENSIONAL DATA WITH A DIGITAL IMAGING SYSTEM

FIELD OF THE INVENTION

The present invention relates to the field of digital image acquisition, and more particularly, to the field of three-dimensional digital image acquisition.

BACKGROUND OF THE INVENTION

Three-dimensional (stereoscopic) imaging dates from very near the invention of photography. N. Niepce, L. J. M. Daguerre, and Henry Fox Talbot invented two very different photographic processes between 1826 and 1837. In 1839 Daguerre, Hippolyte Bayard, and Talbot published details on these two photographic methods. Niepce and Daguerre disclosed a process using photosensitized metal, while Bayard and Talbot disclosed two slightly different processes using photosensitized paper. The process of Niepce and Daguerre, named daguerreotype, was an immediate success, while the paper processes of Bayard and Talbot did not gain prominence until the perfection of bromide papers in the 1880's. While the principles of stereoscopy were known from the early 1800's, the theories remained unproven until 1838 when Sir Charles Wheatstone published, "Contributions to the Physiology of Vision – on Some Remarkable, and Hitherto Unobserved, Phenomena of Binocular Vision" as a paper presented to the British Royal Society. Wheatstone demonstrated that the mind perceives an object in three dimensions because each eye records a slightly different view. In 1839, a Mr. Collen and Talbot created stereoscopic images using Talbot's processes for Wheatstone, and stereoscopic imaging was born.

Throughout the history of photography one of the major difficulties of stereoscopic imaging, has been the requirement of special equipment and techniques to capture and view stereoscopic images. This need for special equipment and techniques contribute to the fact that stereoscopic imaging is so uncommon today. In 1851 Sir William Brewster invented the lenticular stereoscope, the first stereoscopic viewer usable by the average person. Eight years later, in 1859, Oliver Wendell Holmes, along with Joseph L. Bates, constructed the first version of the now famous hand-held stereoscope, commonly referred to as the Holmes stereoscope. Holmes and Bates neglected to patent their invention, and within several years, the Holmes stereoscope was in production by a number of different opticians throughout the United States.

The first stereoscopic images were produced using a single camera that was shifted between exposures. This method is only usable in capturing static images. When movement occurs in the time between the two exposures, the left and right images will capture the moving object at slightly different locations and retinal rivalry will occur. Because of this limitation, a camera capable of capturing simultaneous left and right images is required in most situations. The use of two images to capture three-dimensional information of an object is well known. However, there is a need in the art for an apparatus and method for capturing three-dimensional information from a single image, since such an image capture device would require only a single lens and shutter, thus lowering the cost of such a camera.

Three-dimensional data is also required in the construction of models for use in computer-aided-design (CAD) and computer-aided-manufacturing (CAM) systems. Currently, the generation of three-dimensional data from an existing object is a time-consuming chore. Specialized hardware exists to capture such three-dimensional data,

but may be large and expensive. There is a need in the art for a simple, inexpensive image capture device capable of capturing three-dimensional data.

SUMMARY OF THE INVENTION

A digital image capture device including circuits capable of measuring the distance between the image capture device and an imaged object allows the capture of three-dimensional data of the surface of the object facing the image capture device. The distance data is obtained by the addition of a flash unit, and very high resolution timers to multiple pixels within the image capture device to measure the time required for the flash to reflect from the object. Since the speed of light is constant, the distance from the flash to the object to the image capture device may be calculated from the delay for the light from the flash to reach the device. Multiple pixels may be used to construct a three-dimensional model of the surface of the object facing the image capture device. Multiple images including distance data may be taken in order to generate a complete three-dimensional model of the surface of the object.

Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of an image capture system.

FIG. 2 is a graphical representation of an image capture array.

FIG. 3 is a block diagram of a portion of an image capture system.

FIG. 4 is a flow chart of a process for gathering three-dimensional data with an image capture system.

DETAILED DESCRIPTION

FIG. 1 is a block diagram of an image capture system. The basic components of a digital image capture system are a lens **102** and an image capture array **104** such as a CCD or other device. In capturing an image of an object **106**, the lens focuses an image **108** of the object on the image capture array **104**.

FIG. 2 is a graphical representation of an image capture array **104**. In this particular figure a 15 by 23 array of 345 pixel sensors **200** is shown. Each pixel sensor **200** records light intensity of a portion of the image. The pixel sensors **200** may record only light intensity recording a black and white image, or there may be red, green, and blue pixel sensors **200** in the array recording a color image.

FIG. 3 is a block diagram of a portion of an image capture system. This figure is representative of a single pixel sensor **200** and the devices associated with it to measure distance to the object recorded by that pixel sensor **200**. When a shutter **300** is activated, a timer **304** is cleared, and a flash **302** is fired at the same time the timer **304** is started. Note that in some image capture systems, the flash **302** may be delayed from the activation of the shutter **300**. For example, some systems pre-fire a light or light emitting diode (LED) for red-eye reduction before the main flash **302** is fired. The flash **302** does not have to use visible light. Other possible wavelengths of light, or other energy, may be used, including non-visible wavelengths such as infrared. Use of an infrared flash **302** would allow this invention to be used without a humanly visible flash, that may be required for some applications of the present invention. Also note that in some implementations, the flash may be external to the image capture device and coupled through an electrical connector **322**. The timer **304** does not start counting until the main flash **302** is fired. Once the timer **304** is started, the pixel sensor **200** is monitored until it records a brightening in the image from the flash **302**. This monitoring of the pixel

sensor **200** may be done by an intensity comparator **320** built in to the sensor or the timer, or elsewhere within the circuitry of the image capture device. The amount of brightening of the image required to stop the timer **304** may be specified by a threshold brightness, calculated as a fraction of the initial brightness of the portion of the image recorded by the pixel sensor, or determined by other equivalent means. For example, the timer **304** may be stopped once the brightness increases by 150%. It may be desirable to allow the image capture device to set these thresholds dynamically and simply look for a step function type of change in intensity. Many different threshold mechanisms and methods may be used within the bounds of the present invention. Once the pixel sensor **200** receives the light from the flash **302**, the timer **304** is stopped and the timer data may be stored in a first memory **306**. This first memory **306** in some implementations of the present invention may be as simple as a register contained within the timer **304**. The image data from the pixel sensors **200** is stored in a second memory **308**. Since the speed of light is constant (or nearly so), the distance to the portion of the object imaged by the pixel sensor **200** may be calculated by a converter **310** that converts the timer data to distance data and stores the distance data in a third memory **312**. This circuitry is replicated for a plurality of pixel sensors **200**. It isn't necessary to have timers **304** associated with each pixel sensor **200** in the image capture array **104**. For example, there may be one timer for each 2 X 2 block of pixel sensors **200**, or for each 4 X 4 block of pixel sensors **200**, or any of numerous other possible distributions within the scope of the present invention. When more than one pixel sensor **200** is associated with a single timer, the timer may be controlled by one of the pixel sensors **200**, or a combination of several or all of the pixel sensors **200**. However, when all of the pixel sensors **200** have timers **304** the granularity of the distance data will be equal to the granularity of the image data.

FIG. 4 is a flow chart of a process for gathering three-dimensional data with an image capture system. In a step **400**, the shutter **300** of the image capture device is pressed and control is passed to a step **402** where the intensity value of each pixel sensor **200** coupled with a timer **304** is recorded into one side of the intensity comparator **320**. Control is then passed to a step **404** where all of the timers **304** are cleared, the flash **302** is fired, and all of the timers **304** are started at the time the flash **302** is fired. Control is then passed to a step **406** where the intensity value of each pixel sensor **200** coupled with a timer **304** is checked by the intensity comparator **320**. In a step **408** the timers **304** associated with each pixel sensor **200** that detected the flash **302** are stopped. In a decision step **410**, if a timeout (or maximum allowable time) has been reached control passes to a step **412**. If no timeout or maximum allowable time has been reached, control returns to a step **406**. The timeout or maximum allowable time may be calculated and set in a number of ways within the present invention. Since most flash units **302** have a maximum effective range, it is possible to calculate the time required to travel that distance to the object then back to the image sensor array **104**. Setting the maximum allowable time to this value then ensures that objects within the range of the flash **302** will have their distances to the image sensor array **104** determined, and objects outside the range of the flash will have their distances set to a maximum value. It is also possible to calculate a maximum allowable time from a given maximum allowable distance (possibly set by the user). In a step **412** the timer data **316** from all of the timers **304** is stored in a first memory **306**, and in a step **414** the image data **314** from the image sensor array **104** is stored in a second memory **308**. In an optional step **416**, the timer data **316** from the first memory **306** is converted to distance data **318** (using the known speed of light), and in an optional step **418** the distance data **318** is stored in a third memory **312**.

The foregoing description of the present invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and other modifications and variations may be possible in light of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and various modifications as are suited to the particular use contemplated. It is intended that the appended claims be construed to include other alternative embodiments of the invention except insofar as limited by the prior art.